i

Activity: The Colpitts Oscillator

Objective:

Oscillators come in many forms. In this lab activity we will explore the Colpitts configuration which uses a taped capacitor divider to provide the feedback path.

Background:

The Colpitts Oscillator is a particularly good circuit for producing fairly low distortion sine wave signals in the RF range, 30kHz to 30MHz. The Colpitts configuration can be recognized by its use of a tapped capacitor divider (C_1 and C_2 in figure 1). The frequency of oscillation can be calculated in the same way as any parallel resonant circuit, using:

$$F_R = \frac{1}{2\pi\sqrt{LC}}$$

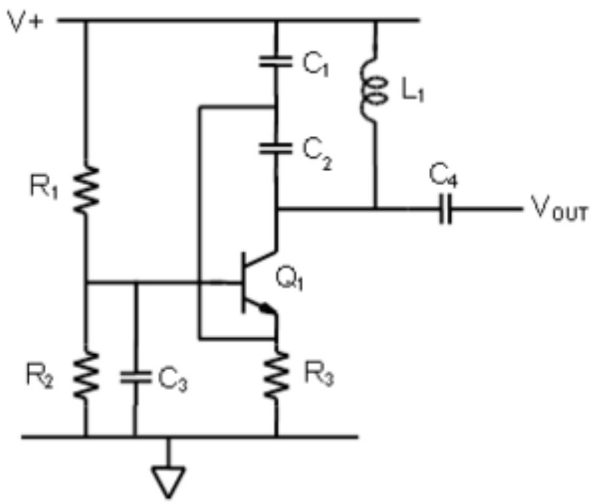
(/_detail/university/courses/electronics/ata1_e1.png?id=university%3Acourses%3Aelectronics%3Acomms-lab-colpitts-osc)

The values of the two capacitors (connected in series) are chosen so their total capacitance in series(C_{TOT}), is given by:

$$C_{TOT} = \frac{C_1 * C_2}{C_1 + C_2}$$

(/_detail/university/courses/electronics/acol-osc_e2.png?id=university%3Acourses%3Aelectronics%3Acomms-lab-colpitts-osc)

Figure 1 shows a typical Colpitts oscillator. The frequency determining parallel resonant tuned circuit is formed by C_1, C_2 and L_1 and is used as the collector load impedance of the common base amplifier Q_1. This gives the amplifier a high gain only at the resonant frequency. This configuration of the Colpitts oscillator uses a common base amplifier, the base of $Q_1$is biased to an appropriate DC level by resistor divider R_1 and R_2 but is connected directly to an AC ground by C_3. In the common base mode the output voltage waveform at the collector, and the input signal at the emitter are in phase. This ensures that the fraction of the output signal from the node between C_1 and C_2, fed back from the tuned collector load to the emitter provides the required positive feedback. Note that this feedback is AC only and there is no DC path from the collector to the emitter.



(/_detail/university/courses/electronics/acol-osc_f1.png?id=university%3Acourses%3Aelectronics%3Acomms-lab-colpitts-osc)

Figure 1 Basic Colpitts Oscillator

The combined capacitance of C_1 and C_2 also forms a low frequency time constant with the emitter resistor R_3 to provide an average DC voltage level proportional to the amplitude of the feedback signal at the emitter of Q_1. This provides automatic control of the gain of the amplifier to regulate the closed loop gain of the oscillator. As with all oscillators, the Barkhausen criteria must be adhered to requiring a total gain of one and a phase shift of zero degrees from input to output. The emitter resistor R_3 is not decoupled because the emitter node is used as the common base amplifier input. The base is connected to AC ground by C_3, which will provide a very low reactance at the oscillator frequency.

Pre Lab Simulations

Build a simulation schematic of the Colpitts oscillator as shown in figure 1. Calculate values for bias resistors R_1 and R_2 such that with emitter resistor R_3set to 1 KΩ, the collector current in NPN transistor Q_1 is approximately 1 mA (milliampere). Assume the circuit is powered from a +10V power supply. Be sure to keep the sum of R_1 and R_2 (total resistance greater than 10 KΩ) as high as practical to keep the standing current in the resistor divider as low as practical. Remember that C_3 provides an AC ground at the base of Q_1. Set base decoupling capacitor C_3 and output AC coupling capacitor C_4 to 0.1uF. Calculate a values for C_1 and C_2 such that the resonate frequency, with L_1 set equal to 100 uH will be close to 500 KHz. Perform a transient simulation. Save these results to compare with the measurements you take on the actual circuit and to include with your lab report.

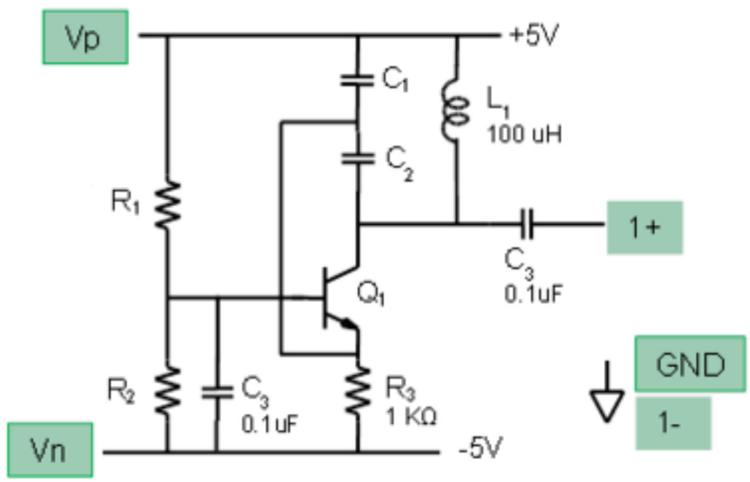
Materials:

ADALM2000 Active Learning Module
Solder-less breadboard, and jumper wire kit
1 - 2N3904 NPN transistor
2 - 10 uH inductors
2 - 100 uH inductors
1 - 1 nF capacitor (marked 102)
1 - 4.7 nF capacitor (marked 472)
2 - 0.1 uF capacitors (marked 104)

1 - 1 KΩ resistor
Other resistor, capacitors and inductors as needed

Directions:

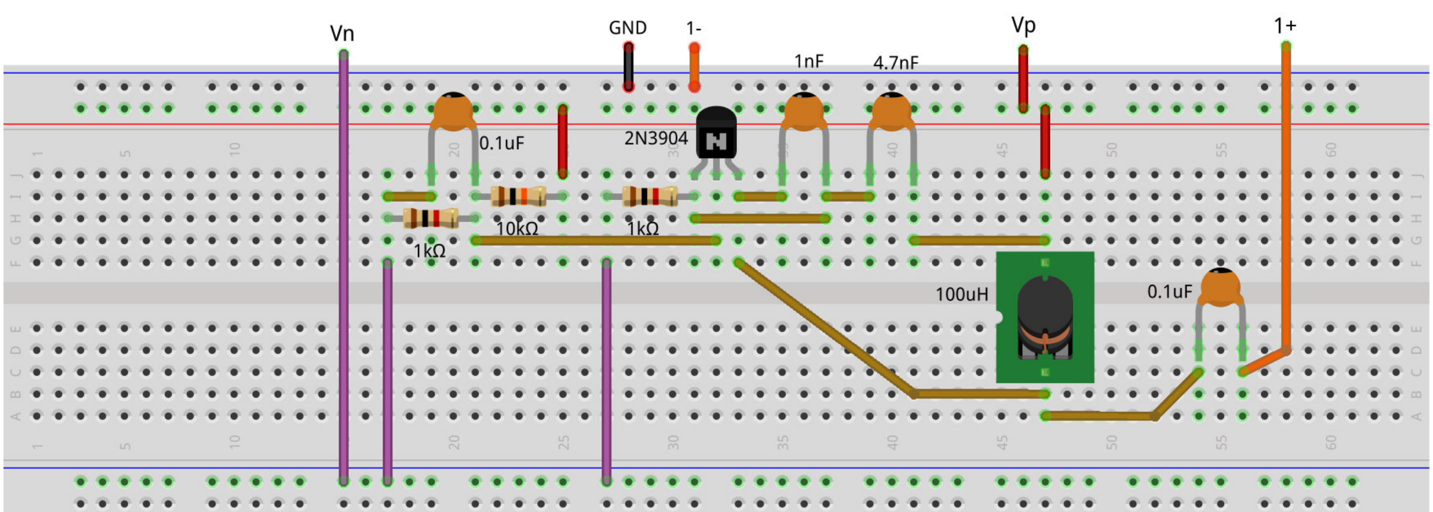
Build the Colpitts Oscillator shown in figure 2 using your solder-less breadboard. Pick standard values from your parts kit for bias resistors R_1 and R_2 such that with emitter resistor R_3set to 1 KΩ, the collector current in NPN transistor Q_1 is approximately 1 mA (milliampere). The frequency of the oscillator can be from around 500 KHz to 2 MHz (megahertz) depending on the values chosen for C_1, C_2 and L_1. Start with L_1 = 100 uH and C_1 = 4.7 nF and C_2 = 1 nF. This oscillator circuit can produce a sine wave output in excess of 10 Vpp at an approximate frequency set by the value chosen for L_1.



(/_detail/university/courses/electronics/acol-osc_f2.png?id=university%3Acourses%3Aelectronics%3Acomms-lab-colpitts-osc)

Figure 2 Colpitts Oscillator

Hardware Setup:



(/_detail/university/courses/electronics/colpitts_osc-bb.png?id=university%3Acourses%3Aelectronics%3Acomms-lab-colpitts-osc)

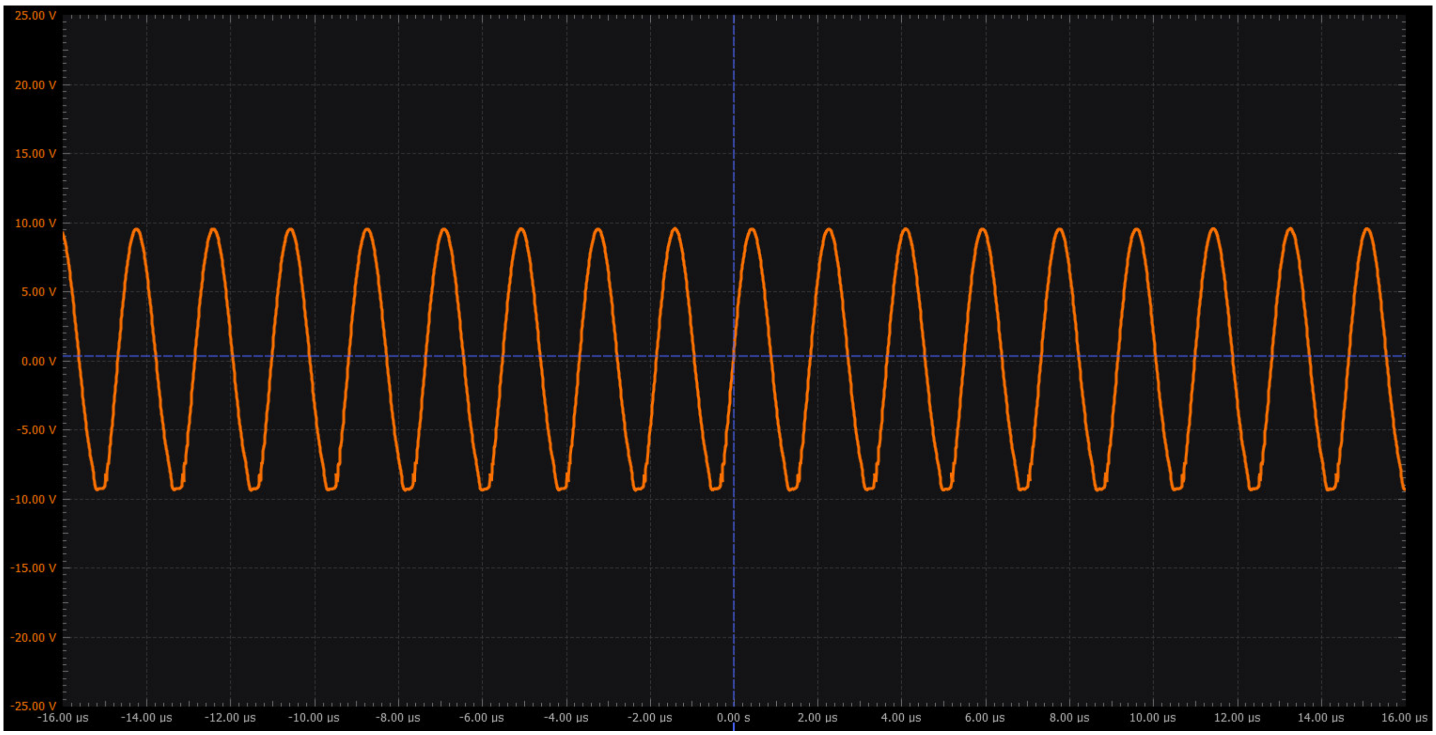
Figure 3 Colpitts Oscillator breadboard circuit

The green squares indicate where to connect the ADALM2000module AWG, scope channels and power supplies. Be sure to only turn on the power supplies after you double check your wiring.

Procedure:

Having finished construction the Colpitts oscillator check that the circuit is oscillating correctly by turning on both the + and - 5 V (volt) power supplies and connecting one of the oscilloscope channels to the output terminal. It may be found that the value of R_3 is fairly critical, producing either a large distorted waveform or an intermittent low or no output. To find the best value for R_3, it could be replaced by a 1 KΩ or 5 KΩ potentiometer for experimentation to find the value that gives the best wave shape and reliable amplitude. The optimal value for R_3 may change depending on the resonate frequency.

A plot example using R_1=10KΩ, R_2=1KΩ, C_1=4.7nF, C_2=1nF is presented in Figure 4.



(/_detail/university/courses/electronics/colpitts_osc-wav.png?id=university%3Acourses%3Aelectronics%3Acomms-lab-colpitts-osc)

Figure 4 Colpitts Oscillator breadboard plot

Questions:

Measure the peak to peak output voltage of the output. Measure the DC (average) level of the output waveform at the collector of Q_1 and on the other (output) side of AC coupling capacitor C_4. Measure the period (time T) of the output waveform and its frequency (1/T). Compare this measured frequency to what you calculated by:

$$F_R = \frac{1}{2\pi\sqrt{(LC)}} .$$

Fill in the table below with the measured frequency for other L_1 values. Use the values in the table as suggested options but try to include as many different values as possible using series and parallel combinations of the inductors supplied in your parts kit. For example a 20 uH inductor value can be made from two 10 uH inductors in series and likewise a 50 uH value can be obtained by connecting two 100 uH inductors in parallel. Any of the L_1 optional values shown below should give reliable oscillation.

L_1 Options	**C_1 = 4.7nF C_2 = 1nF**	**C_1 = 10nF C_2 = 4.7nF**
Value	Frequency	Frequency
10 uH		
20 uH		
50 uH		
100 uH		

Lab Resources:

- Fritzing files: colpitts_osc_bb [https://minhaskamal.github.io/DownGit/#/home?url=https://github.com/analogdevicesinc/education_tools/tree/master/m2k/fritzing/colpitts_osc_bb]
- LTspice files: colpitts_osc_ltspice [https://minhaskamal.github.io/DownGit/#/home?url=https://github.com/analogdevicesinc/education_tools/tree/master/m2k/ltspice/colpitts_osc_ltspice]

For Further Reading:

http://en.wikipedia.org/wiki/Colpitts_oscillator [http://en.wikipedia.org/wiki/Colpitts_oscillator]
http://en.wikipedia.org/wiki/Barkhausen_stability_criterion [http://en.wikipedia.org/wiki/Barkhausen_stability_criterion]

Return to Lab Activity Table of Contents (/university/courses/electronics/labs).

university/courses/electronics/comms-lab-colpitts-osc.txt · Last modified: 27 Mar 2019 12:07 by amiclaus